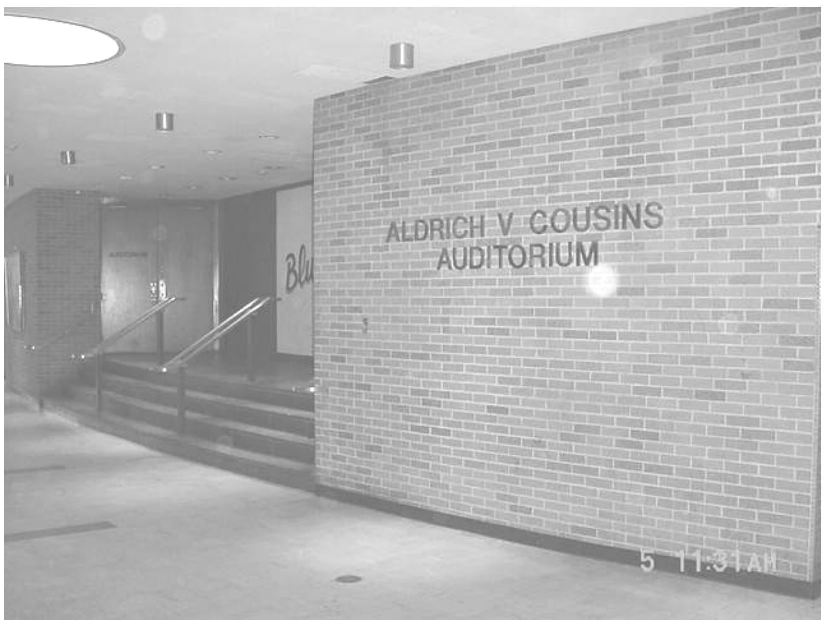
INDOOR AIR QUALITY ASSESSMENT

Aldrich V. Cousins Auditorium
Leominster High School
122 Granite Street
Leominster, Massachusetts



Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Emergency Response/Indoor Air Quality Program

May 2005

Background/Introduction

At the request of parents and Chris Knuth, Health Director, City of Leominster, the Massachusetts Department of Public Health (MDPH), Center for Environmental Health (CEH), provided assistance and consultation regarding indoor air quality concerns at the Aldrich V. Cousins Auditorium at Leominster High School (LHS), in Leominster, Massachusetts. The request was prompted by concerns about water damage and potential mold growth resulting from roof leaks in the auditorium.

On April 5, 2005, a visit to conduct an assessment of the auditorium was made by Cory Holmes, an Environmental Analyst in CEH's Emergency Response/Indoor Air Quality (ER/IAQ) Program. Mr. Holmes was accompanied by David Wood, Director of Facilities, Leominster School Department (LSD); Paul Gentile, Head Custodian; Bill Rodriguez, Jr. Custodian and Mr. Knuth during the assessment. The school was previously evaluated by MDPH staff in October-November 1999, and a report was issued in January of 2000, detailing air quality conditions in the school at that time (MDPH, 2000). It should be noted, however, that the auditorium was not evaluated during the 1999 visit by MDPH, as that investigation was prompted by concerns related to general classrooms, science classrooms and the vocational technical school.

Methods

MDPH staff performed a visual inspection of building materials in the auditorium to assess water damage and/or microbial growth. Due to the height of the auditorium ceiling, examination of water damaged ceiling plaster was observed with a Vivitar Telescopic Viewer. Moisture content of carpeting, plaster and other porous materials prone to moistening was measured with a Delmhorst, BD-2000 Model, Moisture Detector equipped with a Delmhorst Standard Probe. Air tests for carbon dioxide, temperature and relative humidity were conducted with the TSI, Q-TRAK™ IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector (PID).

Results

The auditorium has a capacity of 1,100 and is used for assemblies, fine arts classes and small groups at different intervals during the day. Tests were taken during normal operations at the school. Results appear in Tables 1 and 2.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were below 800 parts per million (ppm) in the auditorium during the assessment, indicating adequate ventilation. However, the auditorium was being used intermittently by small groups during the testing; carbon dioxide levels would be expected to be higher with full occupancy. Mechanical ventilation is provided by air handling units (AHUs) located in a mechanical room. Fresh air is supplied through ceiling mounted air diffusers and ducted back to the AHUs via return vents located beneath the stage. The system is reported by LHS staff to be on a timer so that it operates continuously during the school day. The AHU was operating during the MDPH visit.

To maximize air exchange, the MDPH recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room, while removing stale air from the room. It is recommended that HVAC systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). The date of the last balancing of these systems was not available at the time of the assessment.

The Massachusetts Building Code requires that auditoriums have a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens, a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, see Appendix A.

Temperature measurements ranged from 69° F to 71° F, which were within or very close to the lower end of the MDPH recommended comfort range. The MDPH recommends that indoor air temperatures be maintained in a range of 70° F to 78° F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

The relative humidity measured in the auditorium ranged from 24 to 26 percent, which was below the MDPH recommended comfort range. The MDPH recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

The LHS is a multi-level building with a number of different roofs that cover certain portions of the building (e.g., classroom wings, cafeteria, auditorium). The LHS including the auditorium has a history of chronic roof leaks. The LSD is reportedly in the process of a school-wide roof replacement program. Several portions of the roof at the LHS have been replaced over the last several years, with others in need of replacement (Pictures 1 and 2). Currently, three roof sections (including the auditorium) are under design for bid specification. According to Mr. Wood, the LSD anticipates the replacement of one or two roofs during the summer of 2005. In the interim, on-going attempts are reportedly made to temporarily repair certain areas to prevent water infiltration, as was evident from the number of patches observed (Picture 3). Mr. Wood reported that the LSD's roofing contractor had patched a number of areas above the auditorium the day preceding the MDPH visit, which is shown in Pictures 4 and 5.

MDPH staff examined the roof and found the roof surface to be rippled and bulging in various areas (Picture 6). These problems can eventually result in damage to the roof membrane and create breaches in the building envelope enhancing water penetration into the building.

MDPH staff also examined conditions in the ceiling plenum directly below the auditorium roof. Although signs of chronic water infiltration (e.g., stained ceiling plaster, buckets stationed to catch water, rusting of metal beams and supports) were observed in several areas, no active mold growth was observed (Pictures 7 through 13). Staining in a number of areas was rust colored (due to water passing over oxidized/rusted metal building components) or black (from leaching through asphalt roofing materials).

In order for building materials to support mold growth, a source of moisture is necessary. Identification and elimination of water moistening building materials is necessary to control mold growth. Building materials with increased moisture content over normal concentrations may indicate the possible presence of mold growth. Identification of the location of materials with increased moisture levels can also provide clues concerning the source of water supporting mold growth.

In an effort to ascertain moisture content of building materials in the auditorium, moisture readings were taken in materials that would most likely be impacted by exposure to excess moisture. Building materials tested included plaster ceiling material (in the ceiling plenum above the auditorium), chair upholstery, carpeting throughout the auditorium and the wooden stage floor. As mentioned previously, moisture content was measured with a Delmhorst Moisture Detector equipped with a Delmhorst Standard Probe. The Delmhorst probe is equipped with three lights that function as visual aids that indicate moisture level. Readings that activate the green light indicate a sufficiently dry or low moisture level, those that activate the yellow light indicate borderline conditions and those that activate the red light indicate elevated moisture content. No elevated moisture readings were measured in any of the materials tested at the time of the assessment (Table 2). It is also important to note that the MDPH assessment occurred two days after three days of moderate to heavy rainfall (The Weather Underground, 2005). The only water penetration observed during the assessment was minor pooling that was collecting on a metal support beam in the ceiling plenum. MDPH staff recommended that a bucket be placed under the beam until LSD maintenance staff could verify that the leak was repaired. LHS officials addressed this during the assessment.

It was reported to MDPH staff that several water damaged chairs were found in the auditorium and were subsequently removed (Picture 13). MDPH staff examined every chair in the auditorium for water damage and or possible mold growth. One chair was found with water damage and removal was recommended (Picture 14). Repeated water damage to porous building materials (e.g., upholstered chairs, ceiling tiles, carpet) can result in microbial growth. The US Environmental Protection Agency (US EPA) and the American Conference of Governmental Industrial Hygienists (ACGIH) recommend that porous materials be dried with fans and heating within 24 to 48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If porous materials are not dried within this time frame, mold growth may occur.

Other Concerns

Indoor air quality can be adversely impacted by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion products include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, BEHA staff obtained measurements for carbon monoxide and PM2.5.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address carbon monoxide pollution and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

ASHRAE has adopted the National Ambient Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from 6 criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000a). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS established by the US EPA, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000a).

Carbon monoxide should not be present in a typical, indoor environment. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels.

Outdoor carbon monoxide concentrations were non-detect or ND. Carbon monoxide levels measured in the auditorium were also ND (Table 1).

As previously mentioned, the US EPA also established NAAQS for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. According to the NAAQS, PM10 levels should not exceed 150 micrograms per cubic meter ($\mu g/m^3$) in a 24-hour average (US EPA, 2000a). This standard was adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent, PM2.5 standard requires outdoor air particulate levels be maintained below 65 $\mu g/m^3$ over a 24-hour average (US EPA, 2000a). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, BEHA uses the more protective proposed PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor (i.e. background) PM2.5 concentrations were measured at 8 $\mu g/m^3$. PM2.5 levels measured indoors ranged from 3 to 4 $\mu g/m^3$ (Table 1), which were below background as well as below the NAAQS of 65 $\mu g/m^3$. Frequently, indoor air levels of particulates (including PM2.5) can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulate during normal operations. Sources of indoor airborne particulates may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner and heavy foot traffic indoors.

Indoor air quality can also be impacted by the presence of materials containing volatile organic compounds (VOCs). VOCs are substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the auditorium, air monitoring for TVOCs was conducted. Outdoor air samples were taken for comparison. Outdoor TVOC concentrations were ND. Indoor TVOC measurements throughout the auditorium were also ND (Table 1).

Please note, TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use of TVOC-containing products. No TVOC-containing products were observed to be in use during the assessment.

Conclusions/Recommendations

In view of the findings at the time of the visit, the following recommendations are made:

1. Due to the current condition of the auditorium roof, LSD maintenance staff should continue to monitor the ceiling plenum during heavy rains for active leaks. School occupants who utilize the auditorium should also notify the main office if leaks are observed for prompt remediation.

2. Empty buckets used to collect leaks regularly to prevent standing water, mold growth and associated odors. Clean and disinfect buckets and surface areas around leaks with an appropriate anti-microbial as needed.
3. Until the roof can be replaced, continue working with roofing contractor in making roof repairs as needed to prevent further water penetration.
4. Continue with plans for school-wide roof replacement including the removal of historical "patches" intended for temporary repair. Once roof is repaired consideration should be made to repair/replace water damaged building materials.
5. Remove/replace water damaged chair (#110) identified in Picture 14.
6. Continue to operate mechanical ventilation in the auditorium continuously during periods of school occupancy and change filters as per the manufactures' instructions or more frequently as needed.
7. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
8. Should mold growth occur, disinfect and/or remove mold-contaminated materials in a manner consistent with recommendations found in "Mold Remediation in Schools and Commercial Buildings" published by the US EPA (2001). Copies of this

document can be downloaded from the US EPA website at:
http://www.epa.gov/iaq/molds/mold_remediation.html.

9. Consider adopting the US EPA (2000b) document, "Tools for Schools", to maintain a good indoor air quality environment in the building. This document can be downloaded from the Internet at http://www.epa.gov/iaq/schools/index.html.

10. Refer to resource manuals and other related indoor air quality documents for additional building-wide evaluations and advice on maintaining public buildings. These materials are located on the MDPH's website: http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

References

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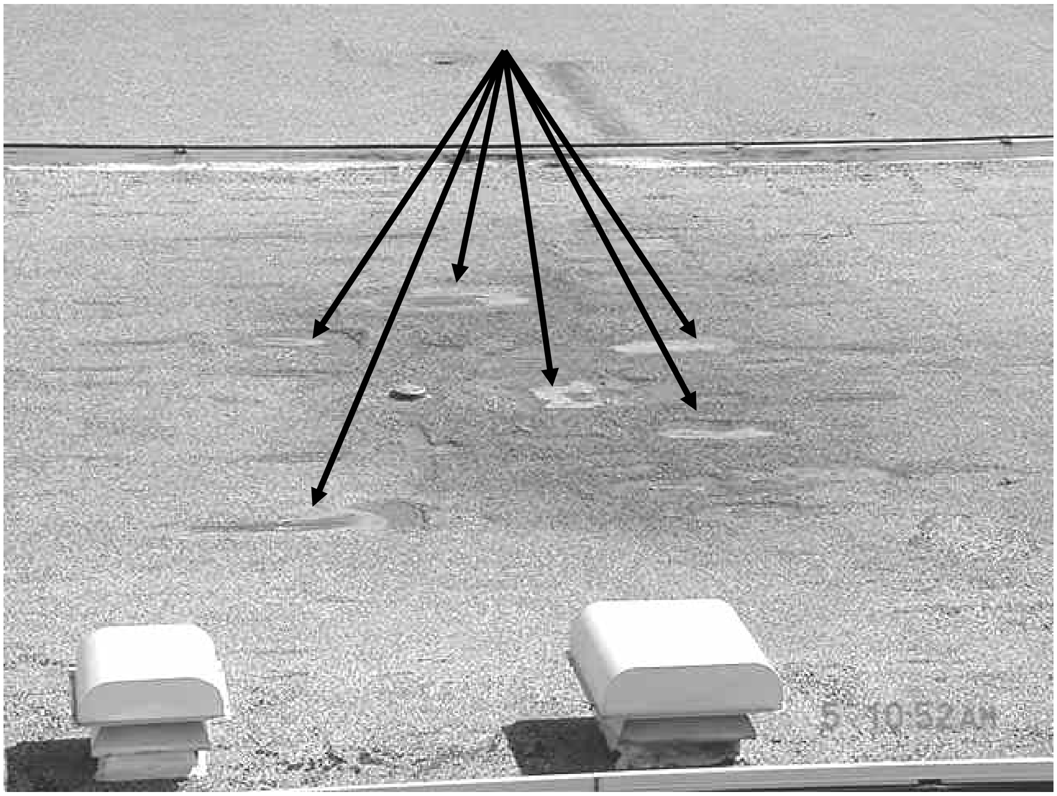
Picture 1

Rubber Membrane Roofs That Have Been Replaced

Picture 2

Old Built-up Roofs (Asphalt/Gravel) in Foreground,
Rubber Membrane Roofs That Have Been Replaced in Background

Picture 3



Previous Roof Patches

Picture 4

“Fresh” Patch on Auditorium Roof

Picture 5

“Fresh” Patches on Auditorium Roof

Picture 6

Bulging/Rippled Roof Surface

Picture 7

Water Damaged/Stained Wall Plaster

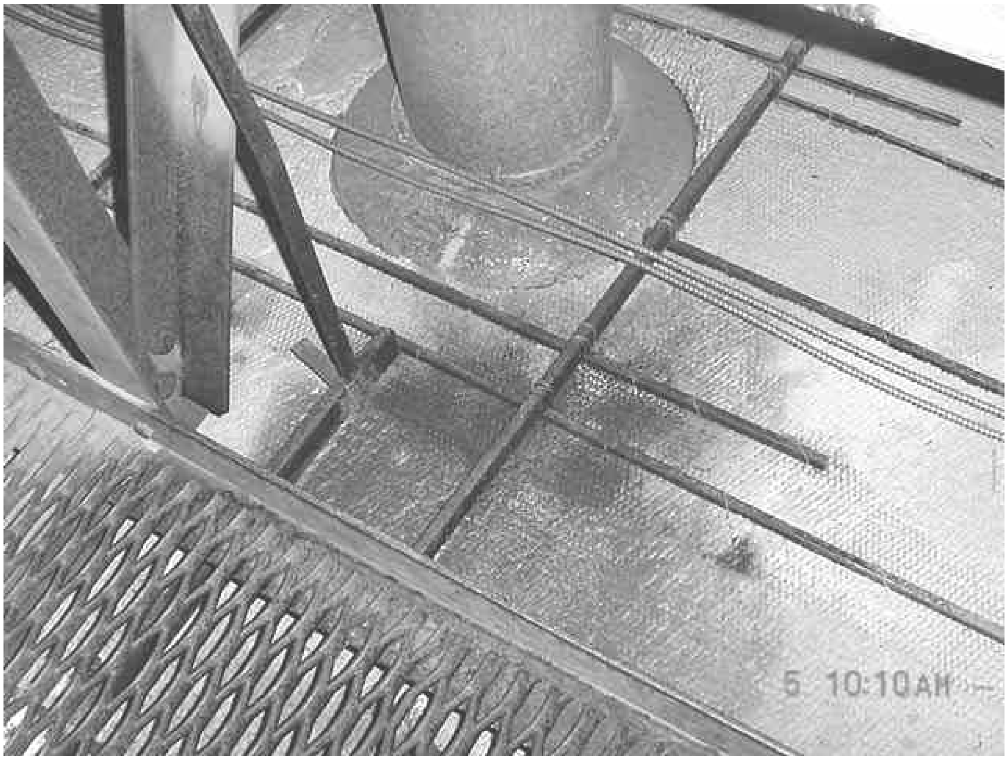
Picture 8

Water Damaged/Stained Ceiling Plaster

Picture 9

Water Damaged/Stained Ceiling Plaster

Picture 10



Water Damaged/Stained Ceiling Plaster in Plenum above Auditorium

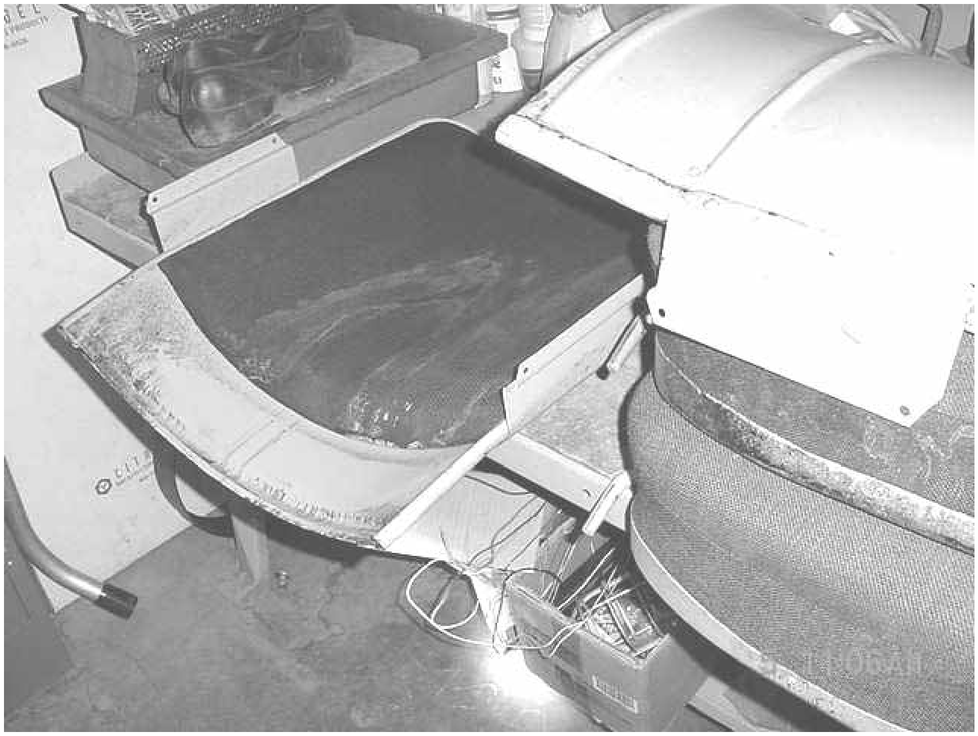
Picture 11

Water Damaged/Stained Ceiling Plaster and Duct Work in Plenum above Auditorium, Note Bucket Used to Catch Rain Water

Picture 12

Water Damaged Wooden Stage Floor

Picture 13



Water Damaged Upholstered Chairs That were Removed from Auditorium
(Picture Taken in Storeroom in Custodians' Office)

Picture 14

Water Damaged Chair (#110)

Aldrich V. Cousins Auditorium, Leominster High School **Indoor Air Results**

122 Granite Street, Leominster, MA **April 5, 2005**

Table 1

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation Supply	Ventilation Exhaust	Remarks
Background (outdoors)	55	20	422	ND	ND	8		-	-	-	Atmospheric Conditions: partly cloudy, warm, west winds 10-15 MPH
Auditorium Center	71	24	582	ND	ND	4	3	N	Y	Y	
Auditorium Center Left	70	24	580	ND	ND	4	0	N	Y	Y	
Auditorium Center Right	71	25	582	ND	ND	3	0	N	Y	Y	
Auditorium Front Center	69	24	586	ND	ND	4	0	N	Y	Y	
Auditorium Front Left	70	25	580	ND	ND	4	0	N	Y	Y	
Auditorium Front Right	71	24	582	ND	ND	4	0	N	Y	Y	WD chair (#110)

ppm = parts per million parts of air
CT = ceiling tile
AD = air deodorizer
AP = air purifier
CD = chalk dust

µg/m3 = microgram per cubic meter
WD = water damage
DEM = dry erase marker
DO = door open
PC = photocopier

UV = univent
CF = ceiling fan
PF = personal fan
TB = tennis balls
UF = upholstered furniture

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

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Auditorium Rear Center	71	24	580	ND	ND	3	0	N	Y	Y	
Auditorium Rear Left	70	25	580	ND	ND	3	0	N	Y	Y	
Auditorium Rear Right	70	24	581	ND	ND	4	0	N	Y	Y	
Stage	71	26	589	ND	ND	4	15	N	Y	Y	WD wooden floor

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TABLE 2

Moisture Test Results
Aldrich V. Cousins Auditorium, Leominster High School
April 5, 2005

Location	Moisture Measurement	Material/Comments
Auditorium Center	Low	Carpet
Auditorium Center Left	Low	Carpet
Auditorium Center Right	Low	Carpet
Auditorium Front Center	Low	Carpet
Auditorium Front Left	Low	Carpet
Auditorium Front Right	Low	Carpet
Auditorium Rear Center	Low	Carpet
Auditorium Rear Left	Low	Carpet
Auditorium Rear Right	Low	Carpet
Chair # 110	Low	Water damaged/stained upholstery
Stage Floor Left	Low	Water damaged wood
Ceiling plenum	Low	Water damaged/stained ceiling plaster, readings taken in multiple areas in the ceiling plenum where water penetration was evident

Note: Dew point on this date was: 24° F